ESA On-board Software Systems Section

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Requirements Modelling: A Verification Method for ISVV

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Outline

- Background
- Purpose of activity
- Activity roadmap
- Activity execution
  - Modelling
  - Model checking
  - Contribution to validation
- Conclusions, product findings and process improvements

Background

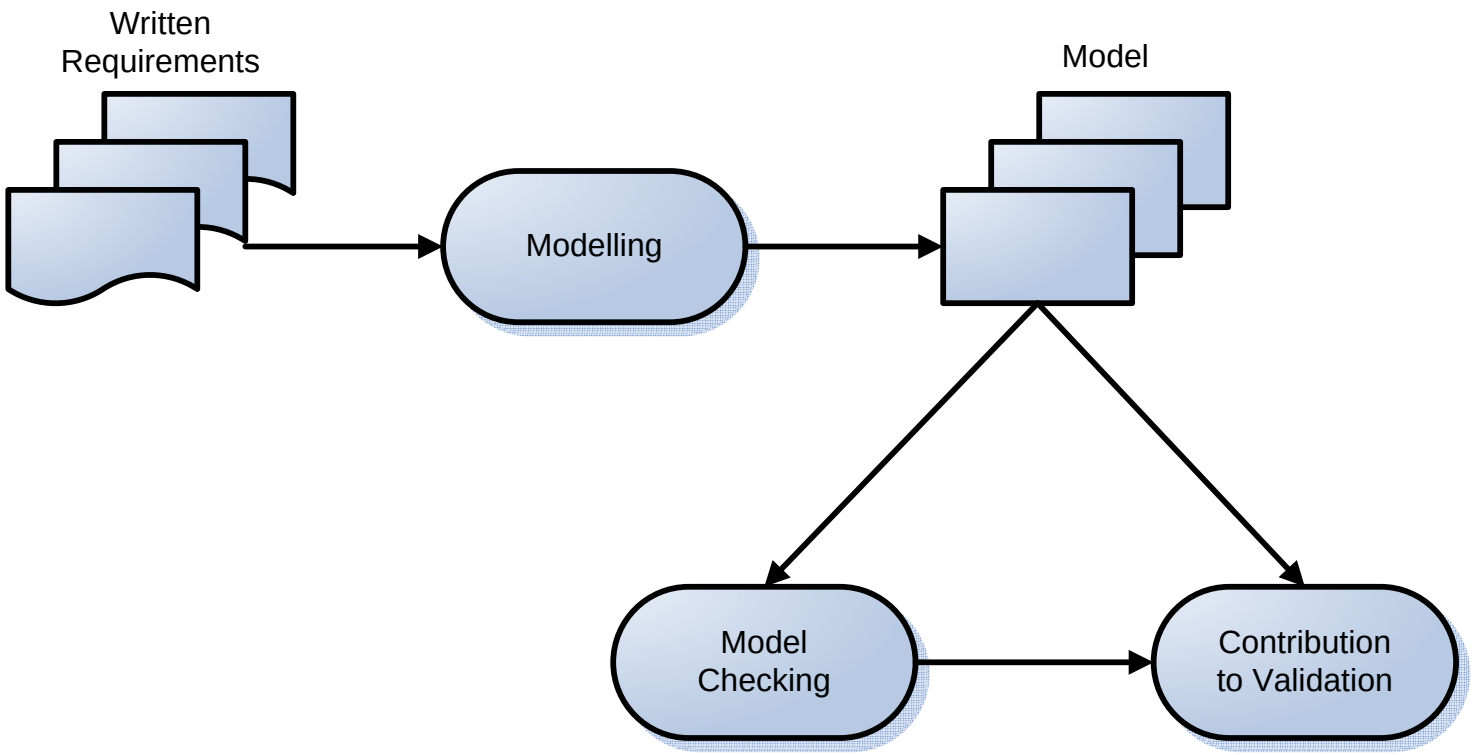
- ESA has initiated a number of activities for ISVV method assessment and process improvement for cost and effort efficiency
- ESA ISVV Guide, Issue 2, contains improvements in all method areas
- This presentation is limited to requirements verification and validation with focus on UML/SysML modelling

Goal

- Assess requirements modelling and model checking as methods for requirements verification

- That is,
  - Take requirement specification written in plain English
  - Create a corresponding model
  - Use various model checking tools to verify the specification
  - Contribution to Validation: Definition of test cases

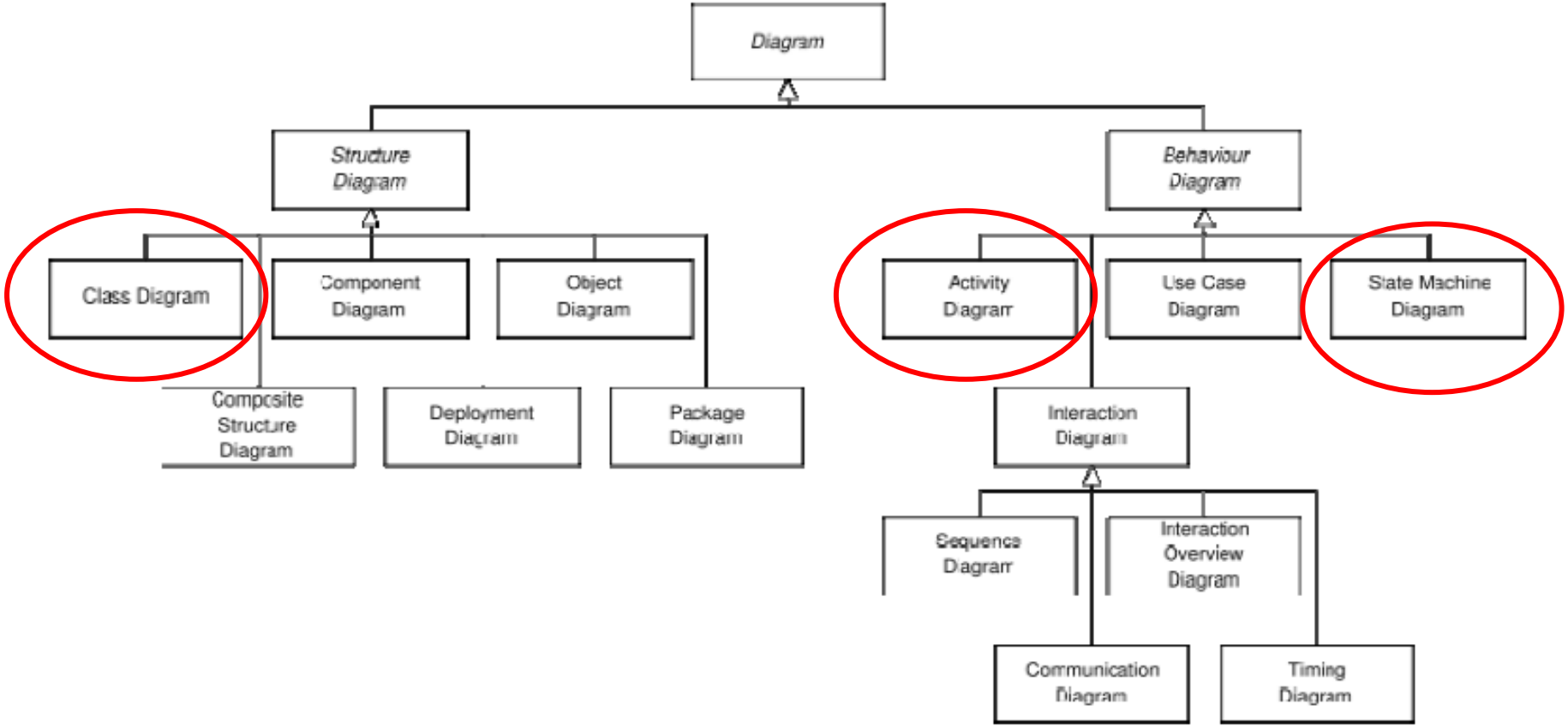
Activity Roadmap



Which “Model Checking”?

- Formal: Maude
  - model execution, proving properties
- Semi-formal: UML Object Constraint Language (OCL)
  - Magic Draw (SysML)
- Informal: Checklists for dependability
  - Using the SysML model

Reference Model in UML



UML Class Diagram

- Classes represent concepts in the system and their associations
- Class diagram provides the system overview

- Findings:
  - Internal inconsistencies (same aspects modelled differently in different diagrams)
  - Completeness: Unspecified multiplicities

UML Activity Diagram

- Defines activities and their flow control
- Concurrent activities

- Findings:
  - Concurrent execution
    - Related activities not being specified
  - Error conditions and FDIR
    - Related error conditions not specified
    - Missing requirements defining alternative behaviours

UML State Machine Diagram

- Used to express states of the system and corresponding state transformations

- Findings:
  - Pairs of states not been taken into account
  - Transitions not being specified
  - Missing guards on transitions

UML Requirements Modelling: Overall Assessment

- UML is easy to use
  - It is flexible in having many different diagram types
  - It is flexible in the use of the diagrams
- Difficult to find a “good” UML representation
  - UML is a graphical tool, not a method
- Difficult to find/select correct abstraction level
  - Due to flexibility (e.g. messages in sequence diagrams)
- Flexibility of UML allows imprecise and informal models
  - E.g. messages in sequence diagrams
  - But formal models are difficult to comprehend…

UML Model Checking (I)

- Mapping between formal semantics of UML and model checking language
- Determine relevant types of checks
  - Model checking can be used to verify that all possible runs of a model satisfies the properties
  - Especially useful for multithreaded systems
- Model checking language – specialist needed

UML Model Checking (II)

- Formalising requirements/models removes ambiguity and helps requirements review
- Executable models increase understanding

- UML diagram does not contain enough information to create formal model, assumptions have to be introduced
- UML diagram has to be constrained to allow model checking translation

- When complexity of model increases the number of possible states increases exponentially – state explosion
- Abstraction can be used but keep in mind that you verify a simplified model
- Findings were done as part of the formalisation, no findings when executing model – all findings related to completeness
  - Could be that the use case was too simple (Data Handling)

Maude: An Example

```
rl [A-acquire-lock] :
      < "Object A" : Object | needResource : "Sensor" >
      < "Sensor" : SharedResource | isLockedBy : null >
      =>
      < "Object A" : Object | needResource : "Sensor" >
      < "Sensor" : SharedResource | isLockedBy : "Object A" > .
```

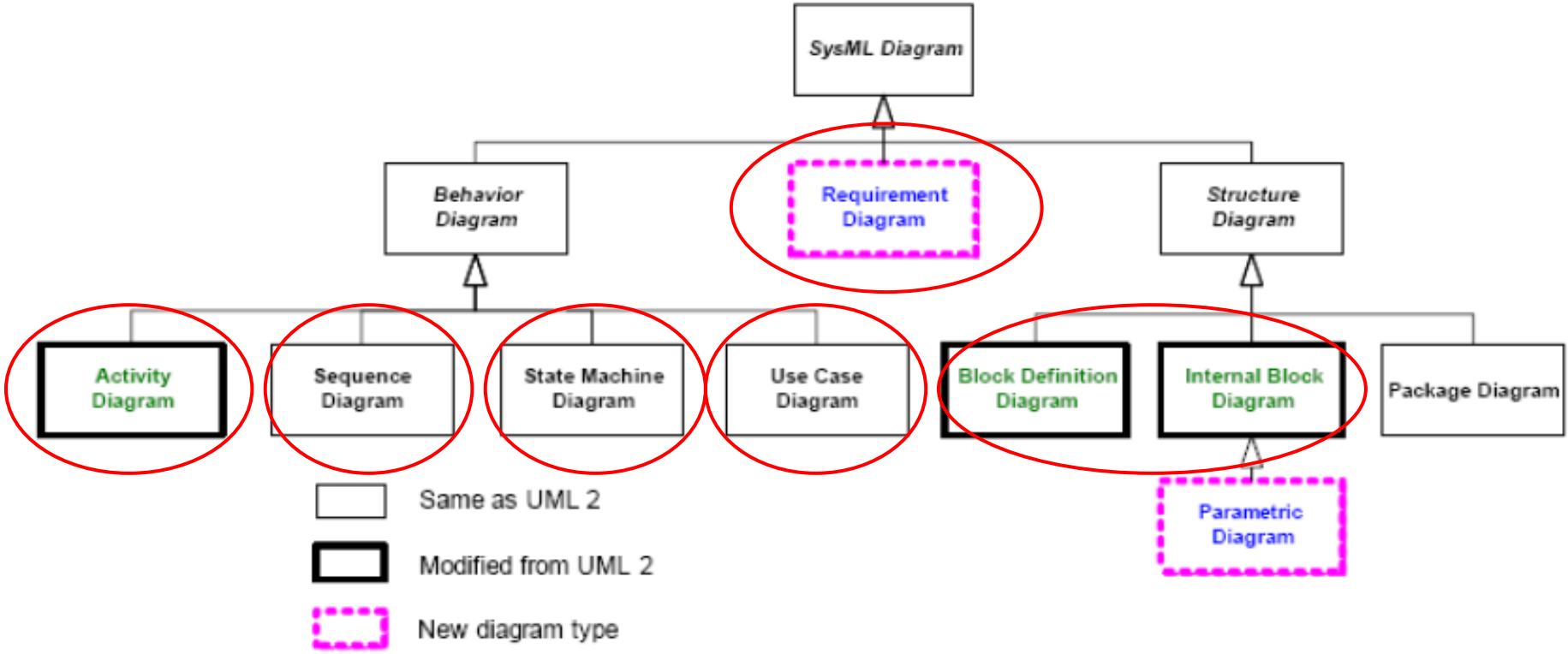
- The part before "=>" specifies what must be the state of the model for the rule to be applicable
- The part after "=>" specifies how the system transforms if the rule is applied

UML Model Checking: Summary

- UML tool: Enterprise Architect (Sparx Systems)
- Approx. 2-3 hrs per requirement for modelling!

- 34 findings
  - 24 finding during modelling
  - 10 during model checking or pre-modelling reading
  - Findings related to missing or incomplete requirements
- Model checker: Maude
- Manual translation to Maude
  - Translation from UML to model checker language not supported:

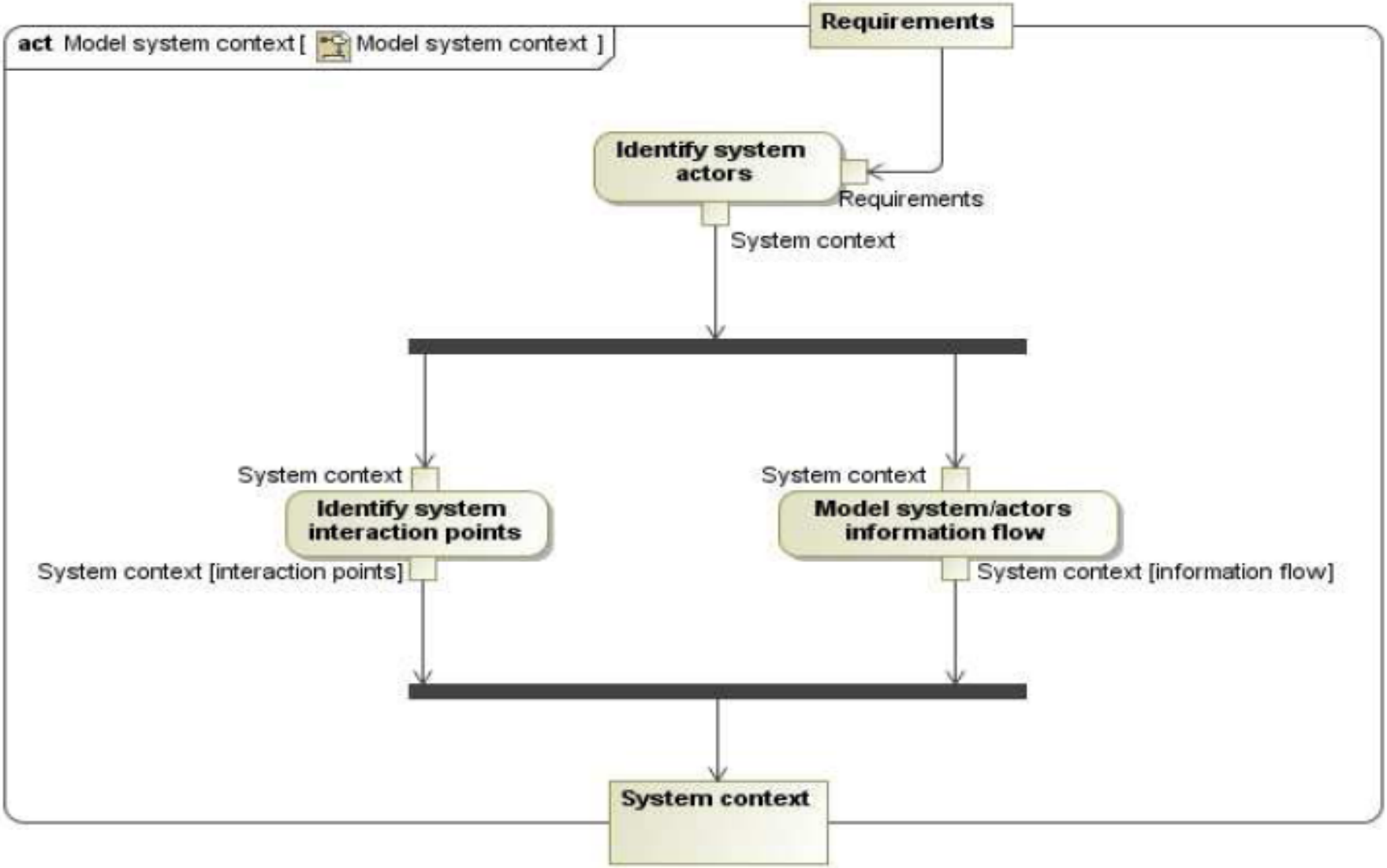
Modelling in SysML



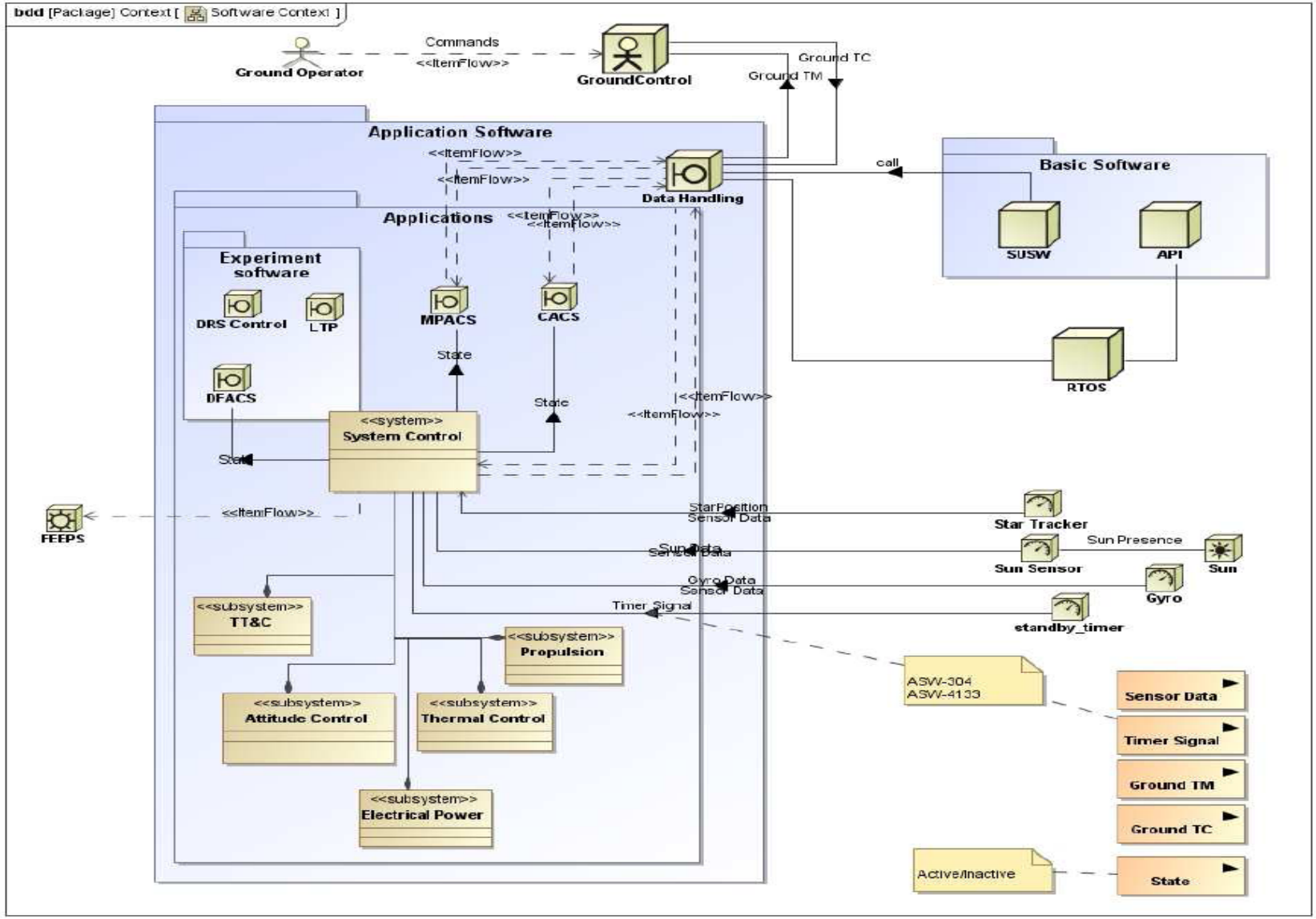
Requirements Modelling in SysML (I)

- Add requirements identifier to the model
  - Storing text in a standardized format
  - Relate requirements between themselves
    - Associations between requirements
    - Associating the same requirement with several elements
    - Visualize requirements
    - Maintaining and tracking of requirements and their relationships
- Model system context (not a predefined diagram)
  - Represent direct environment
  - Initial information about communication flow to and from system
  - Further detailed level, incoming and outgoing information and identifying and analysing actor by actor

Model for System Context



System Context with Information Flows



Requirements Modelling in SysML (II)

- Advantages
  - Integrates requirements
- Difficulties
  - System context definition
  - Correct adjustment of details required
  - When are requirements fully realized?
- Possibly improvements
  - Replace use cases with high-level activity diagram

SysML Modelling: Summary

- SysML tool MagicDraw from No Magic Inc.
- 250 requirements
  - 163 diagrams (block, activity, use cases etc)
  - Approx. 2hrs per requirement!
  - Approx. 60 findings during the modelling process
    - 50 completeness
    - 10 consistency

SysML Model Verification

- Model checking based on OCL scripts
  - Predefined suits for correctness
  - Predefined suits for completeness
  - Additional rules
- Manual checking based on checklist for dependability
- Findings
  - Few from predefined OCL suites
  - More from customized OCL suites
  - In total the number of findings was small comparing to the modelling phase
  - No finding from checklist

Examples of OCL Rules

CORR-01	Max_composite_multiplicity_1	error	Max multiplicity on composed end should be 1
CORR-02	no_method_for_abstract_operation	error	Abstract operation can not have method defined
CORR-03	operation_and_classifier_abstract	error	If at least one operation of classifier is abstract, classifier should be abstract
CORR-04	datatype_operation_is_query	error	Operations of datatype must be queries
CORR-05	Leaf_not_abstract	error	Leaf Element should not be abstract
CORR-06	no_inheritance_from_leaf	error	Can not inherit additional classes from a leaf element

CMP-07	States_incoming	warning	State is without incoming transitions
CMP-08	Name_for_actor	error	Actors should be named
CMP-09	operation_for_callmessage	error	Call message should have operation assigned

SML-05	Viewpoint3	warning	The property ownedAttributes must be empty
SML-06	Block1	warning	Property metaclass that is typed by a block and is owned by an Association may not have a name and may not be defined as a navigable owned end of the association.
SML-07	BlockProperty1	warning	The type of the block property must be a block

Contribution to Validation

- How can modelling and/or model verification contribute to validation
  - I.e. how can this method for requirements verification support identification of validation test cases

- Test cases identification
  - Based on the missing requirements
  - Generating test case and comparing with the test cases identified by the software supplier
    - Tedious work

Conclusions (I)

- Requirements verification through modelling forces verifier to understand the system
- Depending on modelling approach, do we get the same or different findings?
- Most findings identified during the modelling phase
- Model checking revealed few findings only, often already found earlier
  - Possibly because of already performed verification activity

Conclusions (II)

- Modelling promoted as requirements verification method
- Model checking found not mature yet
- Contribution to validation still to be assessed properly